REMARKS

Claims 16-26 are pending in the application.

The following are additional arguments and comments, along with attachments, in support of the patentability of the claims over the prior art.

In the Office Action mailed April 3, 2002, claims 16-18, 20-22, 25 and 26 were rejected under 35 U.S.C. §103(a) as being unpatentable over Juskey, Jr. et al. (U.S. Patent No. 4,940,181). Claims 19, 23 and 24 were rejected under 35 U.S.C. §103(a) as being unpatentable over Juskey, Jr. et al. in view of Okuyama (JP 4-65130). This rejection was a final rejection.

This rejection is respectfully traversed.

This rejection was maintained by the Advisory Action mailed September 30, 2002. The Advisory Action advised that the claim amendments of the Amendment Under Rule 116 filed September 4, 2002 will not be entered. This RCE requests entry of the claim amendments of the Amendment Under Rule 116.

The invention of the present application relates to the art of semiconductor devices to be flip chip bonded to a substrate, and more particularly, relates to a process for the production of such a semiconductor device.

A general process for flip chip bonding a semiconductor device to a substrate is illustrated in attached Figs. 1A to 1H.

Fig. 1A shows, at the left side, a silicon wafer on which a number of semiconductor devices are fabricated together, and, at the right side, a section of an electrode pad of aluminum of a fabricated semiconductor device formed on the wafer with passivation.

On the electrodes of the devices, UBMs (Under Bump Metals, which are referred to as laminated layers in the specification of the present application) of, for example, Ni and Au are formed (Fig. 1B). Solder balls are then formed on the UBMs.

Traditionally, the formation of bumps is carried out by a printing process, in which solder paste is applied onto each of the UBMs, and is then fused for reflowing at an elevated temperature to be bonded to the electrode through the UBM, during which the solder paste is formed into a dome-like shape by the action of surface tension. Alternatively, a solder material is plated on the UBMs using a photo resist mask, the solder is then raised to an elevated temperature to be fused and formed into a dome-like shape. See Figs. 1C and 1D attached hereto.

The wafer is then diced to provide individual chips (semiconductor devices), as shown in Fig. 1E. The chip is connected to a mounting substrate by flip chip bonding the bumps of the chip to the electrodes of the substrate. For the bonding, a flux is applied to the electrodes of the substrate so that the bumps are connected to the electrodes of the substrate through the intervening flux. The assembly of the chip and the substrate is then heated to an elevated

temperature to fuse the solder bumps and accomplish the bonding of the chip to the substrate. See Fig. 1F.

If the heights of the bumps vary widely in this stage, the connection between the bumps and the electrodes of the substrate is frequently bad. Therefore, it is important that the bumps formed at the stage depicted in Fig. 1D have uniform heights or volumes. In other words, the variation in the heights or volumes of the bumps is one of the main causes of fault of an expensive semiconductor device (see the right side of Fig. 1H).

Appendix I, attached hereto, illustrates the three processes for the formation of bumps.

The process of the invention of the present application provides a semiconductor device having solder balls on its electrodes, as shown in the right column of Fig. 1C, which are made into bumps having a uniformity of heights after reflowing (Fig. 1D). This is feasible by the use of the solder balls, the balls being uniform in their heights (or diameters), which is a feature of the present invention. See Appendix II, attached hereto.

As shown in the right column of Fig. 1C, according to the present invention, the solder balls are adhesive bonded to the electrodes of the semiconductor device (chip) with the flux. Thus, the semiconductor device produced, in accordance with the present invention, comprises the solder balls provided on its electrodes, with the balls being fixed to the electrodes by the adhesion of the flux, and having not yet been reflowed. When the semiconductor device is mounted on a substrate, such as a printed circuit board, the solder

balls are reflowed at an elevated temperature and are formed into bumps, which are uniform in their height because of the use of the solder balls which are uniform in diameter. As such, the semiconductor device produced by the process of the present invention does not have bumps but does have solder balls.

The semiconductor device thus produced can be isolated, as a chip, from others by dicing a wafer, and solder balls can be then fixed to the UBMs of the electrodes of the device (chip). Using this device (chip) of the present invention, the electrical connection between the solder balls (bumps) and the electrodes of the device and the electrical connection between the solder balls (bumps) and the electrodes of a substrate can be simultaneously achieved. Thus, the device obtained according to the process of the present invention allows flip chip bonding of the device to a substrate by one heating (reflowing) process. Furthermore, the device provides the bumps certainly connecting the electrodes of the device to the electrodes of the substrate. In addition, according to the present invention, solder balls can be selectively provided only on the devices (chips) having no defect. These benefits cannot be obtained using conventional techniques for the formation of bumps (evaporation, plating, and screen printing). See Appendix II attached hereto.

For the purpose of reference, the attached article, Micro-Ball Wafer Bumping For Flip Chip Interconnection, demonstrates the superiority of the unreflowed solder ball to bumps formed by a conventional process, such as evaporation,

plating, or printing. In particular, Fig. 12b compares height variation of bumps formed from solder balls with bumps formed from printed solder paste. (It should be noted that although Fig. 12b of the article contains two graphs, the upper graph was designated as Fig. 12a when the authors, including the inventors of the present application, sent the draft to IEEE, as can be seen in Appendix III).

Juskey, Jr. et al. cited by the Office Action relates to the bonding of a chip to a substrate, which corresponds to the step illustrated in Fig. 1F. The chip is provided with bumps which have been already connected to the electrodes of the chip through a reflowing process. In contrast, the device (chip) produced by the present invention is provided with solder balls fixed (adhesive bonded) to its electrodes through a flux, and does not have bumps resulting from the reflowing of the bump material. In other words, the bumps of the chip of Juskey are electrically connected to the electrodes of the chip, whereas the balls of the device (chip) obtained according to the present invention are not electrically connected to its electrodes since the balls have not been subjected to a reflowing process and there is flux between the balls and the electrodes. Subsequently, the balls are fused by reflowing before or when mounting the device to a substrate, to be thereby formed into bumps electrically connecting the device to the substrate.

Flux is also used in Juskey. However, the flux is for the bonding of the chip to the substrate using the bumps provided on the chip, and is applied to the electrodes of the substrate. In Juskey, the bumps are formed by a conventional

bump formation process, such as plating, screen printing, or evaporation, as discussed above, without using flux.

As such, Juskey neither discloses nor suggests the process for producing a semiconductor device in accordance with the present invention.

It is therefore submitted that claims 16-26 are patentable.

CONCLUSION

An action on the merits is respectfully requested.

Please charge any required fee associated with this Request For Continued Examination (RCE) and this application to Deposit Account No. 11-0600. A duplicate of this paper is enclosed for deposit account charging purposes.

Respectfully submitted,

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